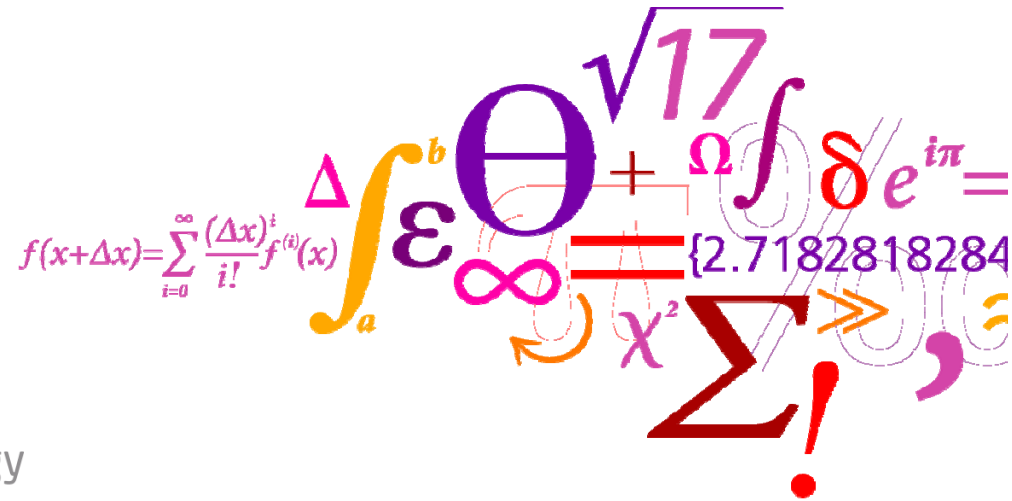
Storm Control and Reliability Indexes of Offshore Wind Farms

Cutululis, Nicolaos Antonio

Publication date:
2009

Storm Control and Reliability Indexes of Offshore Wind Farms

Nicolaos A. Cutululis



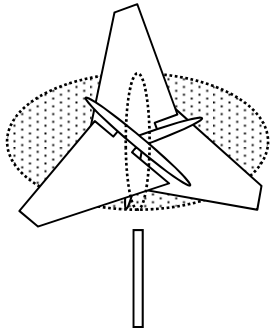
Risø DTU
National Laboratory for Sustainable Energy

Outline

- Wind power fluctuation model
- Storm control
- Simulation scenarios
- Simulation results
- Conclusions

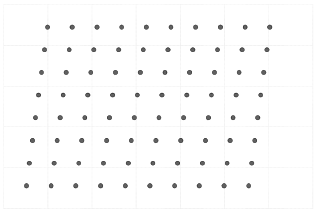
Wind power fluctuation models

2002



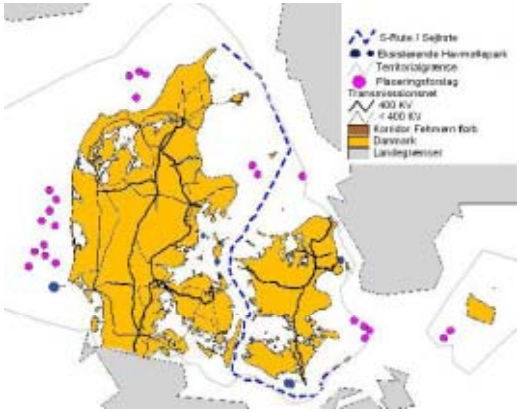
Wind turbine(s)

2007



Wind farm

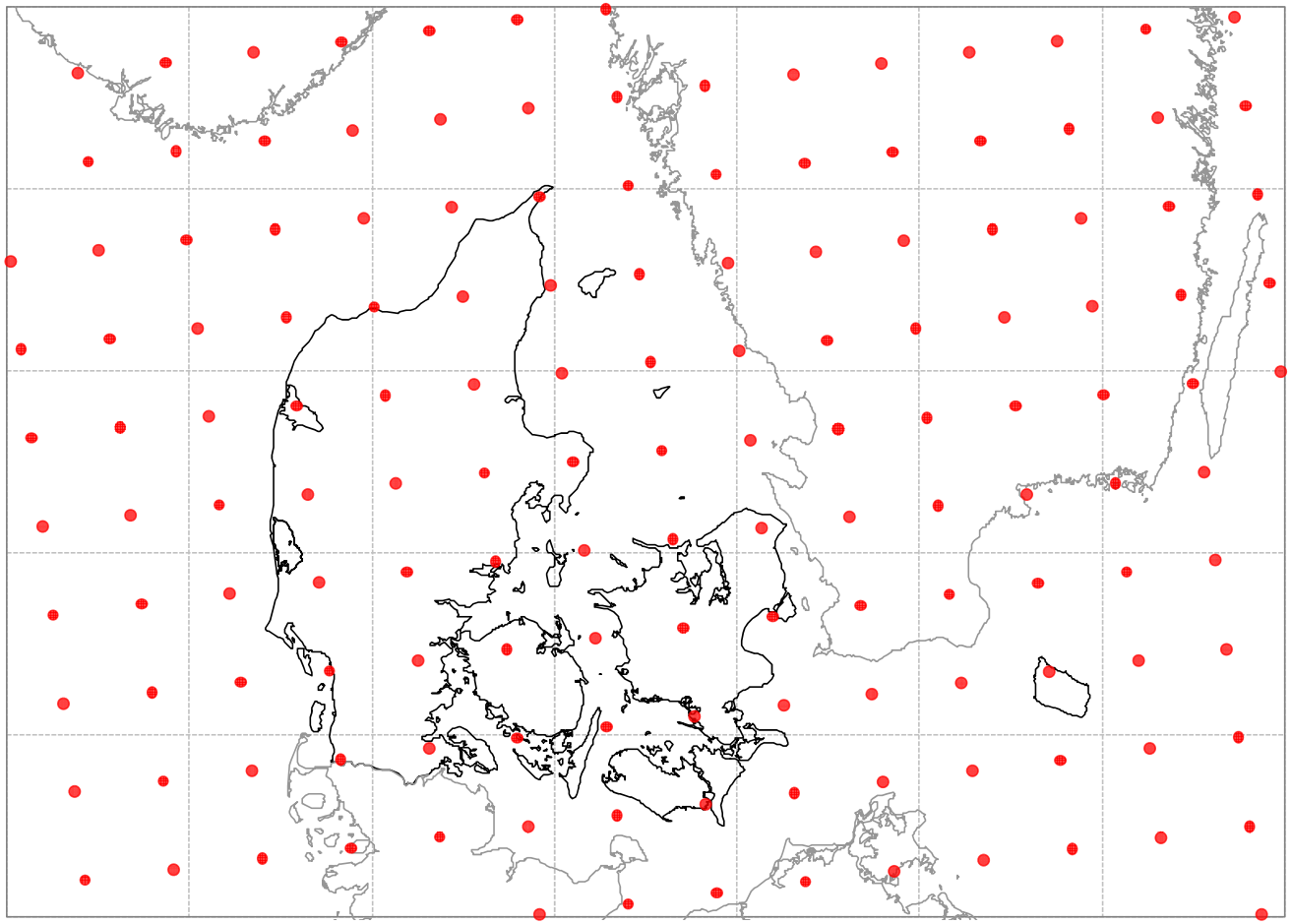
2009



Power system area

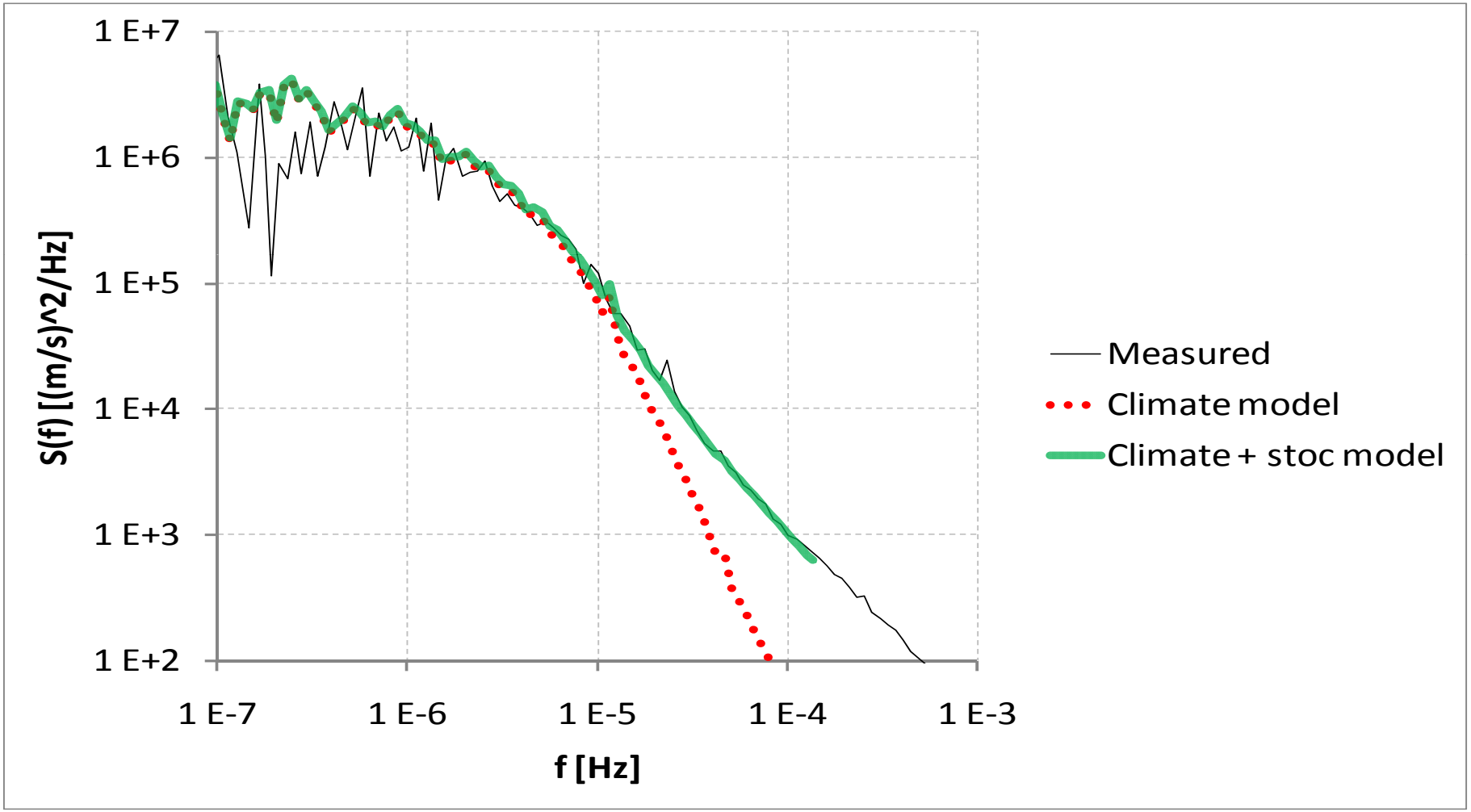
Climate model resolution

Supplied by MaxPlank Germany
25 years of data
1 hour 50 km resolution

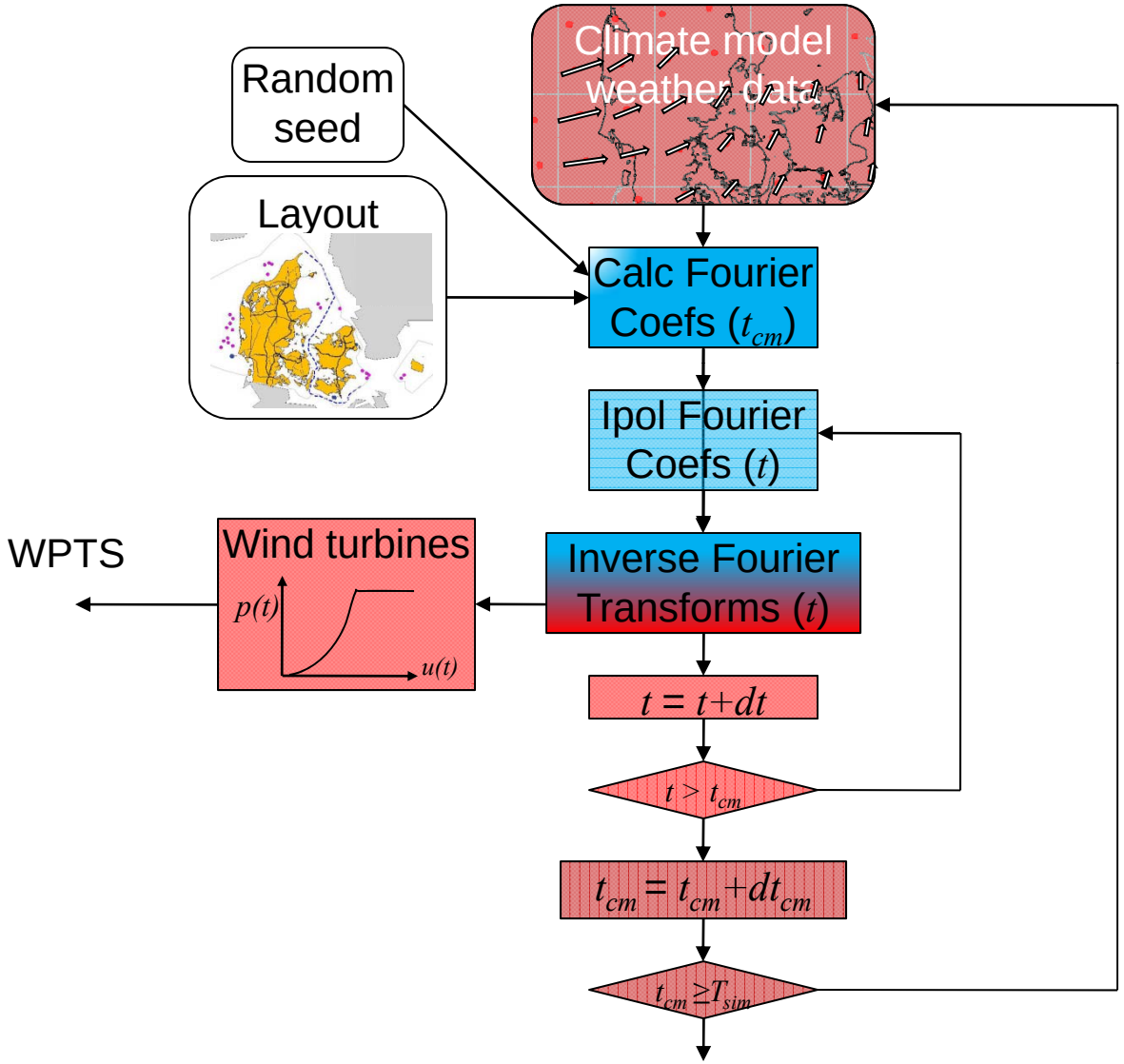


Climate model + stochastic model

Horns Rev example

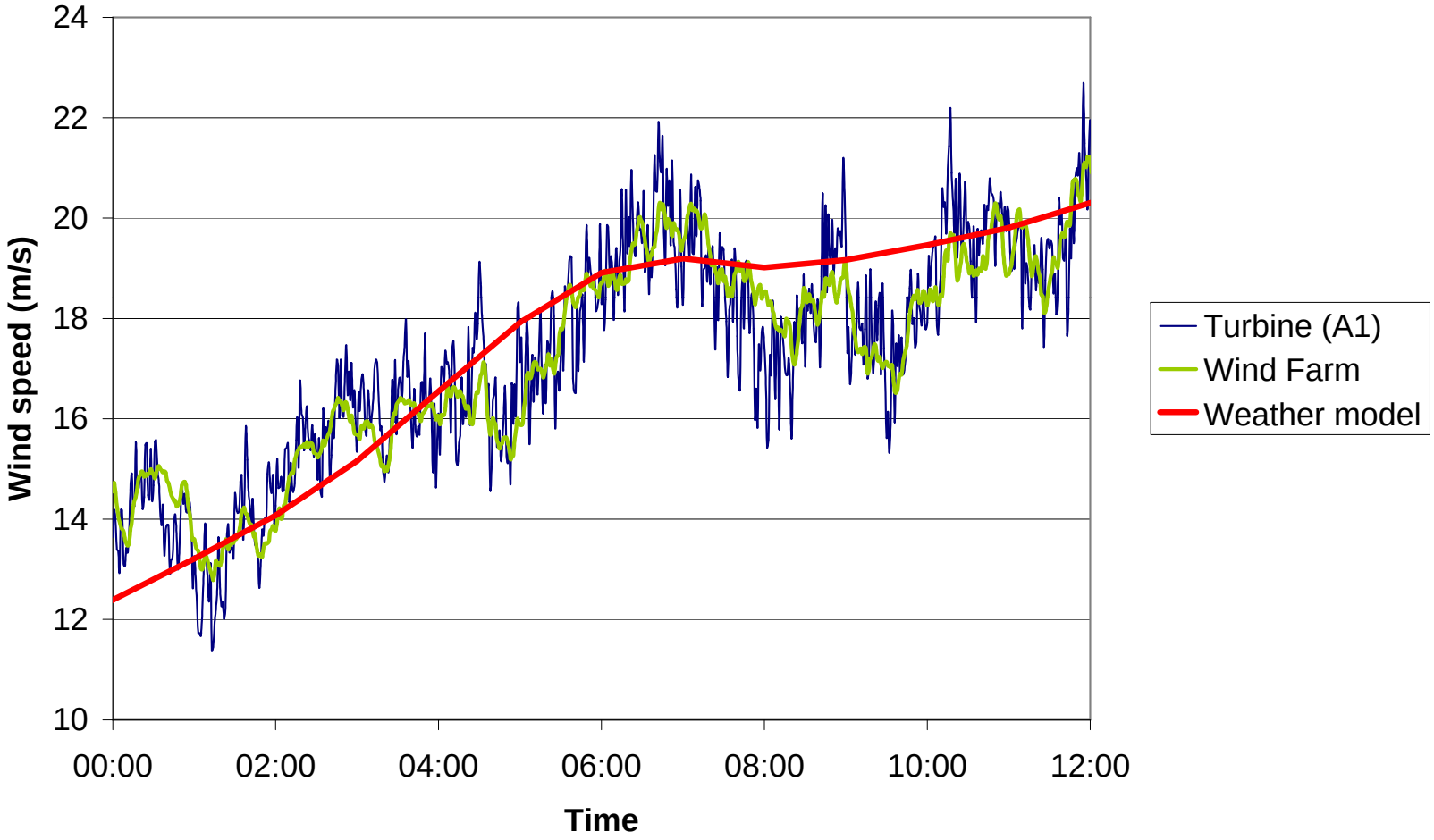


Region wind power model - CorWind

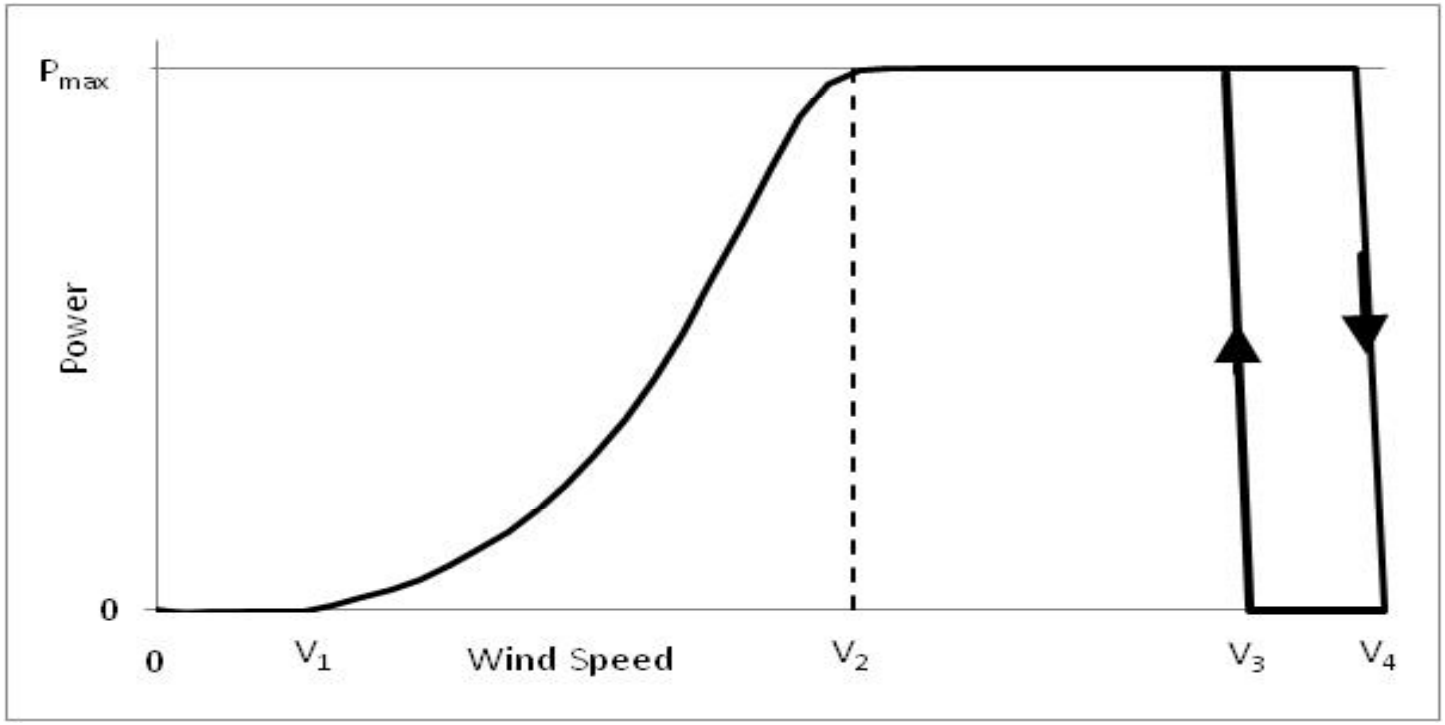


- Input parameters
- Frequency domain
- Time domain (eg. min step)
- Time domain (eg. h step)

Simulated wind speeds - smoothing

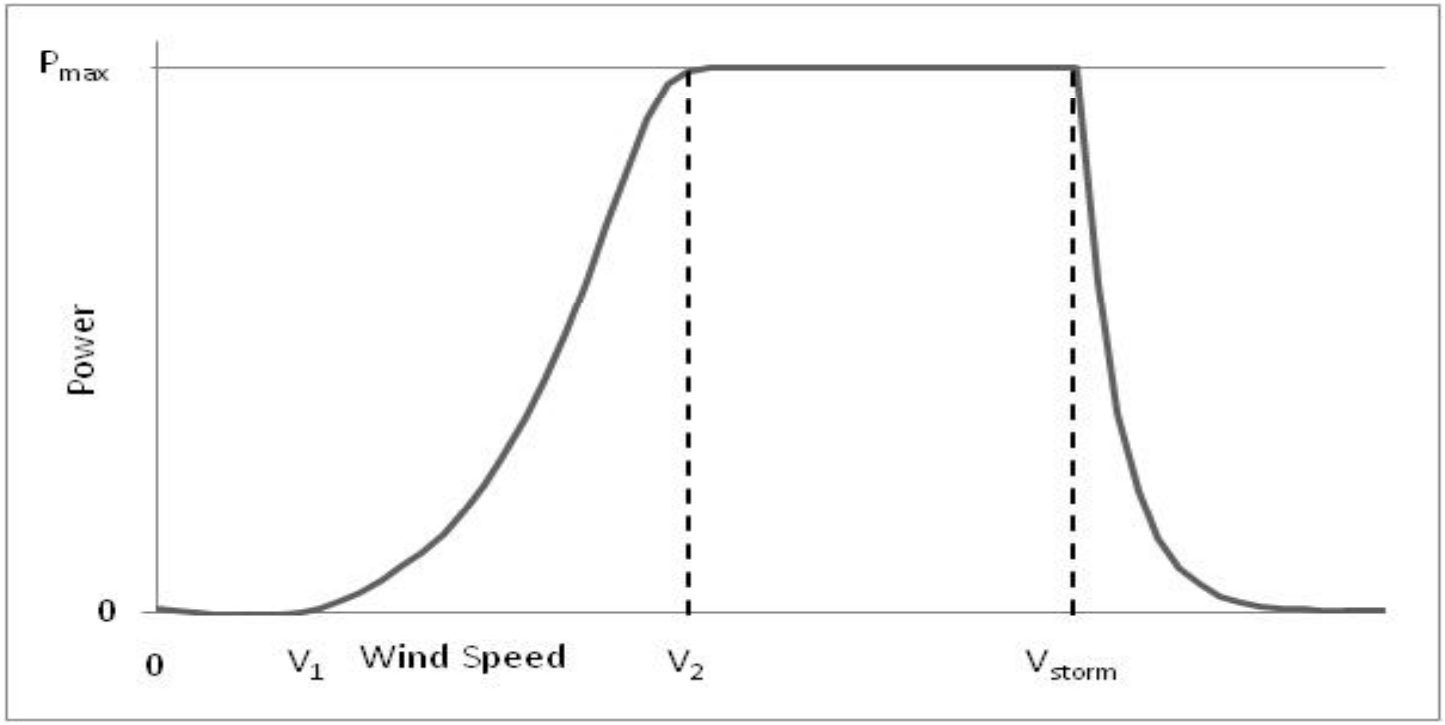


Storm Control



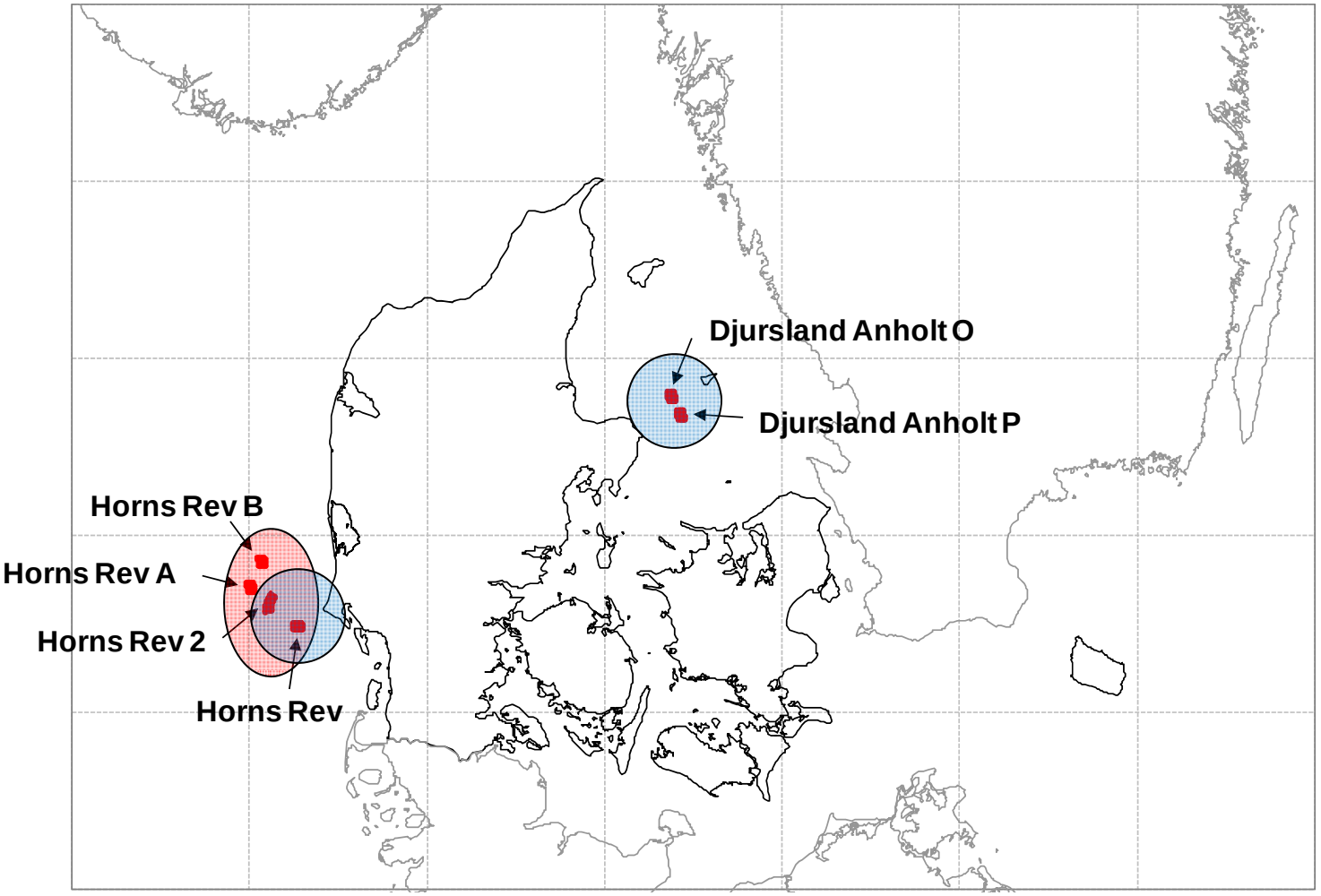
Hysterezis Storm Transition (HST)

Storm Control



Soft Storm Transition (SST)

Simulation cases



Simulation cases

Name	Symbol	Wind turbine power	Total power	Annual mean wind speed
Horns Rev	HR1	80 X 2.0 MW	160 MW	9.6 m/s*)
Horns Rev 2	HR2	91 X 2.3 MW	209 MW	10.4 m/s*)
Horns Rev A	HRA	40 X 5.0 MW	200 MW	10.6 m/s*)
Horns Rev B	HRB	40 X 5.0 MW	200 MW	10.5 m/s*)
Djursland Anholt O	DAO	40 X 5.0 MW	200 MW	9.0 m/s*)
Djursland Anholt P	DAP	40 X 5.0 MW	200 MW	9.0 m/s*)

*)the annual mean wind speeds are assumed, not measured

Simulated 5 years (1999 – 2003) with five different random seeds for the stochastic part – 25 annual wind power time series

Simulation results

1. Frequency and Duration of Occurrence

2. Lost Energy (capacity factor)

3. Ramp Rates and Reserves Requirements

Simulation results

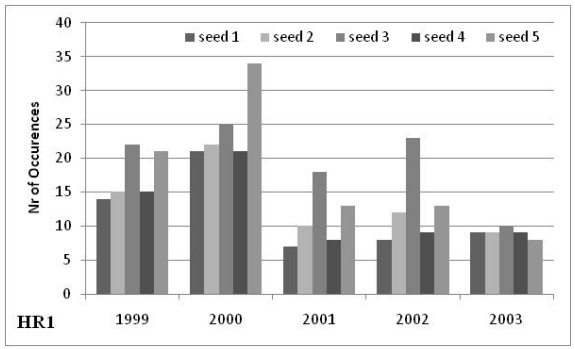
1. Frequency and Duration of Occurrence

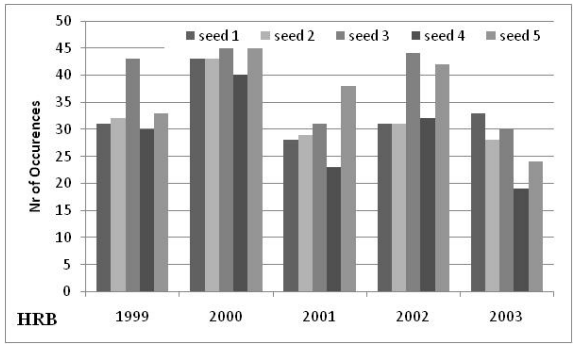
2. Lost Energy (capacity factor)

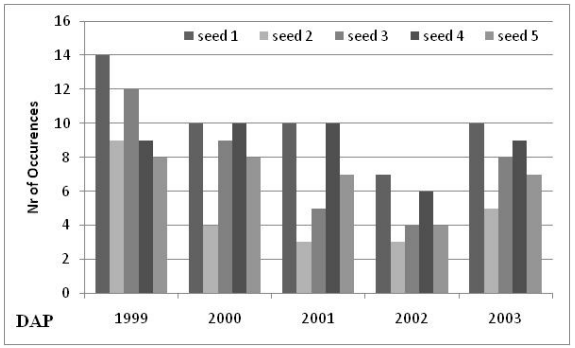
3. Ramp Rates and Reserves Requirements

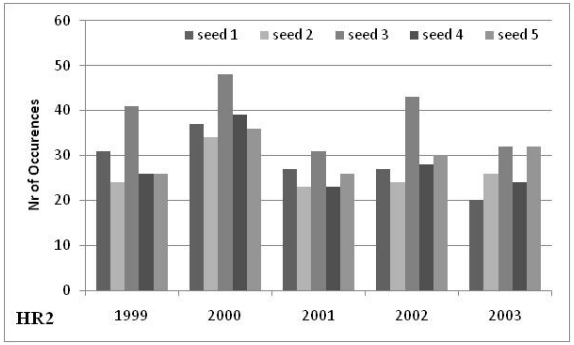
Frequency and Duration of Occurrence

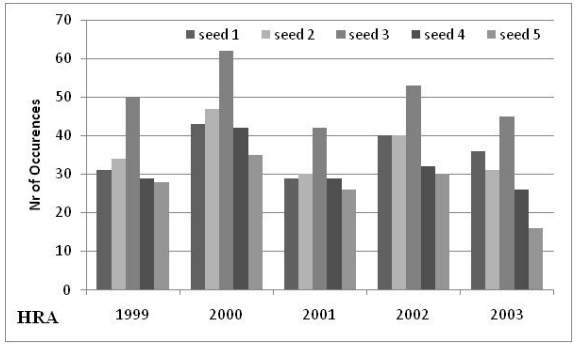
Wind farm level

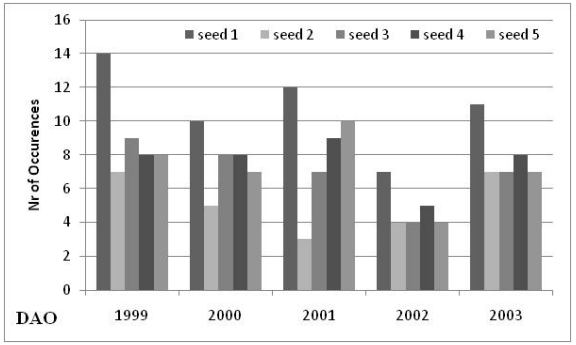






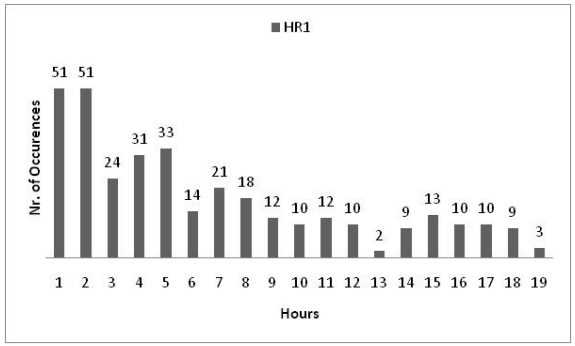


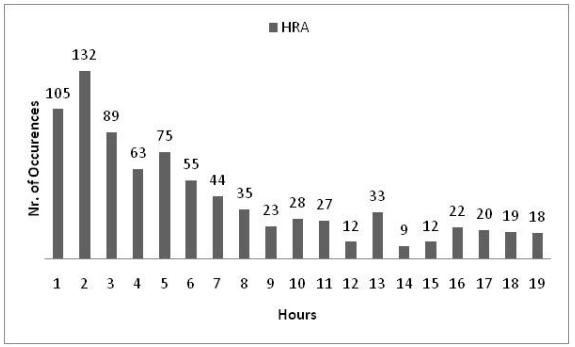


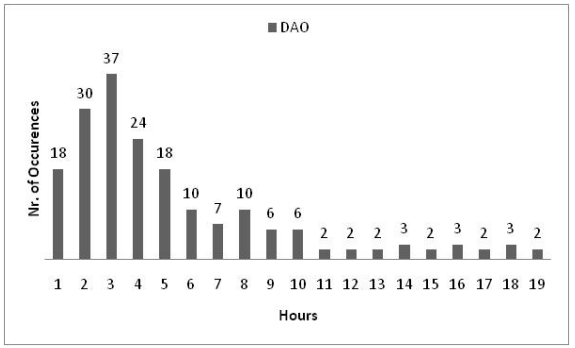


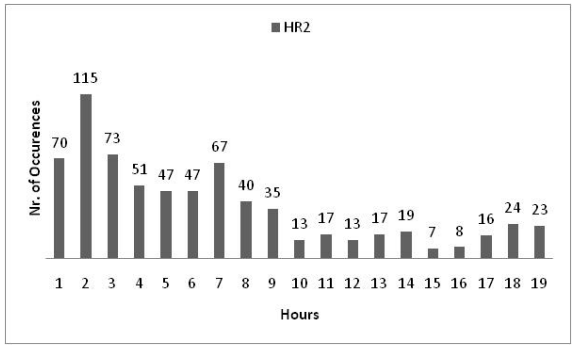
Frequency and **Duration of Occurrence**

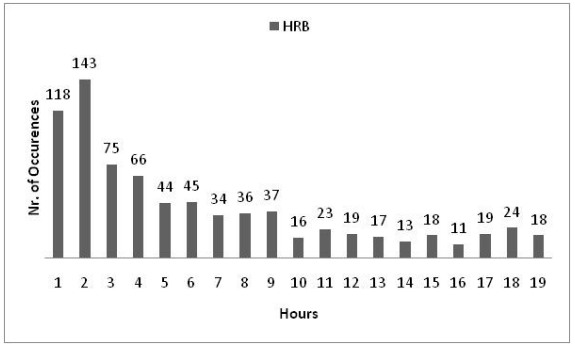
Wind farm level

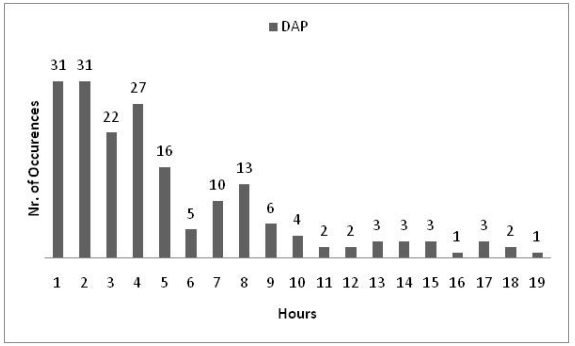






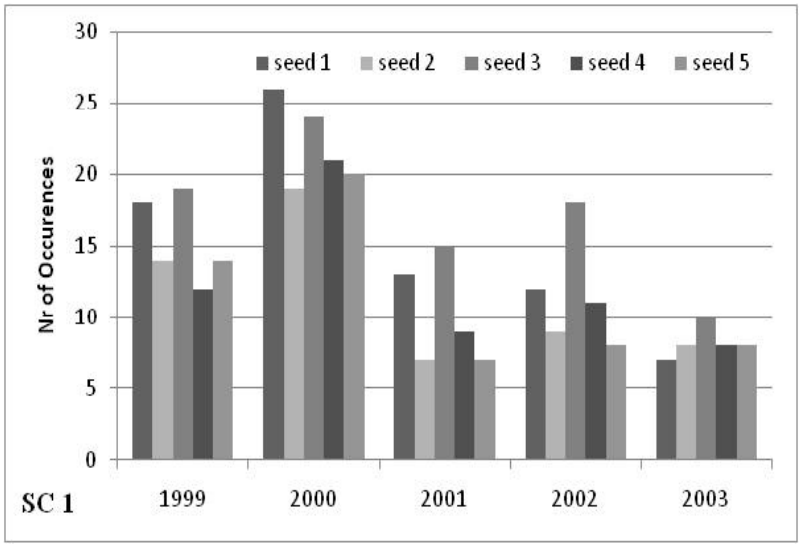


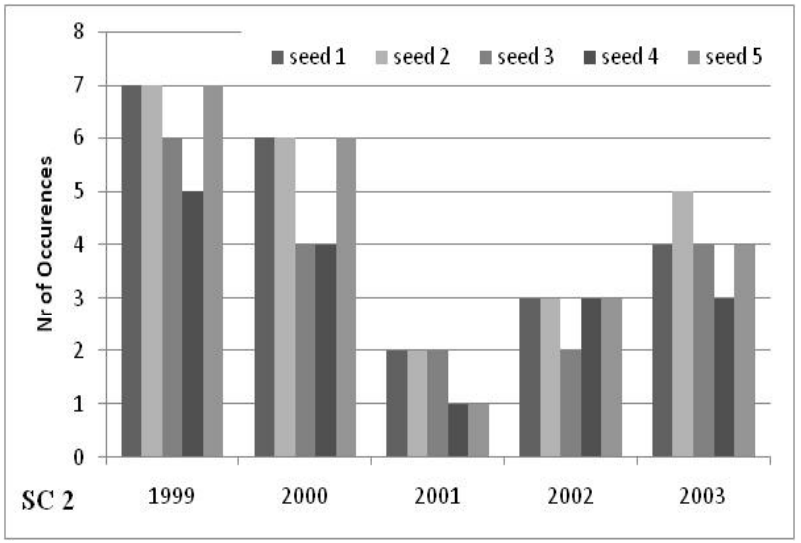




Frequency and Duration of Occurrence

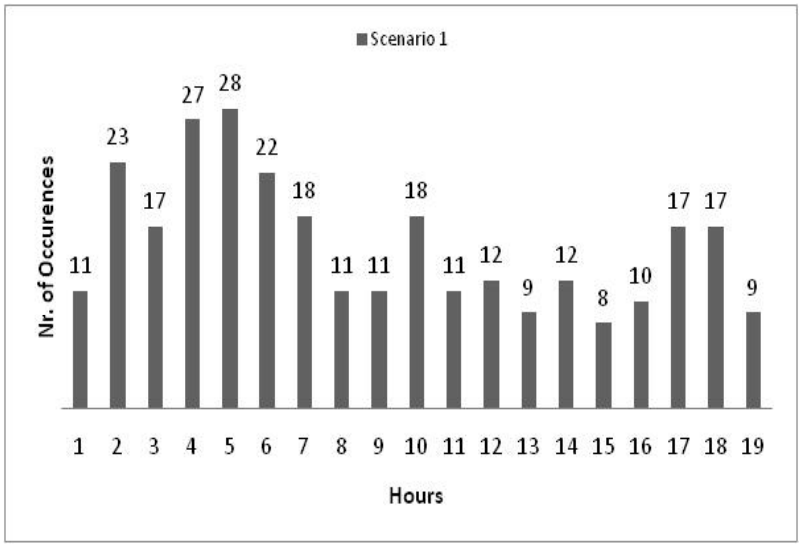
Wind power region level

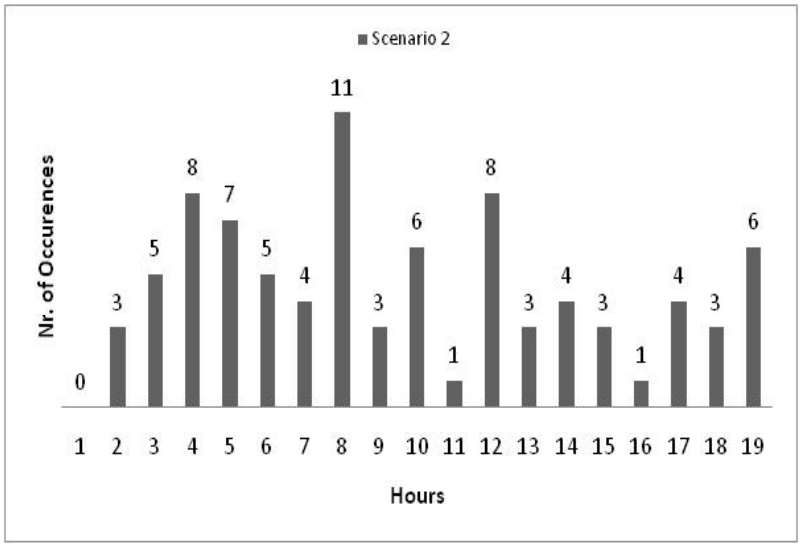




Frequency and **Duration of Occurrence**

Wind power region level





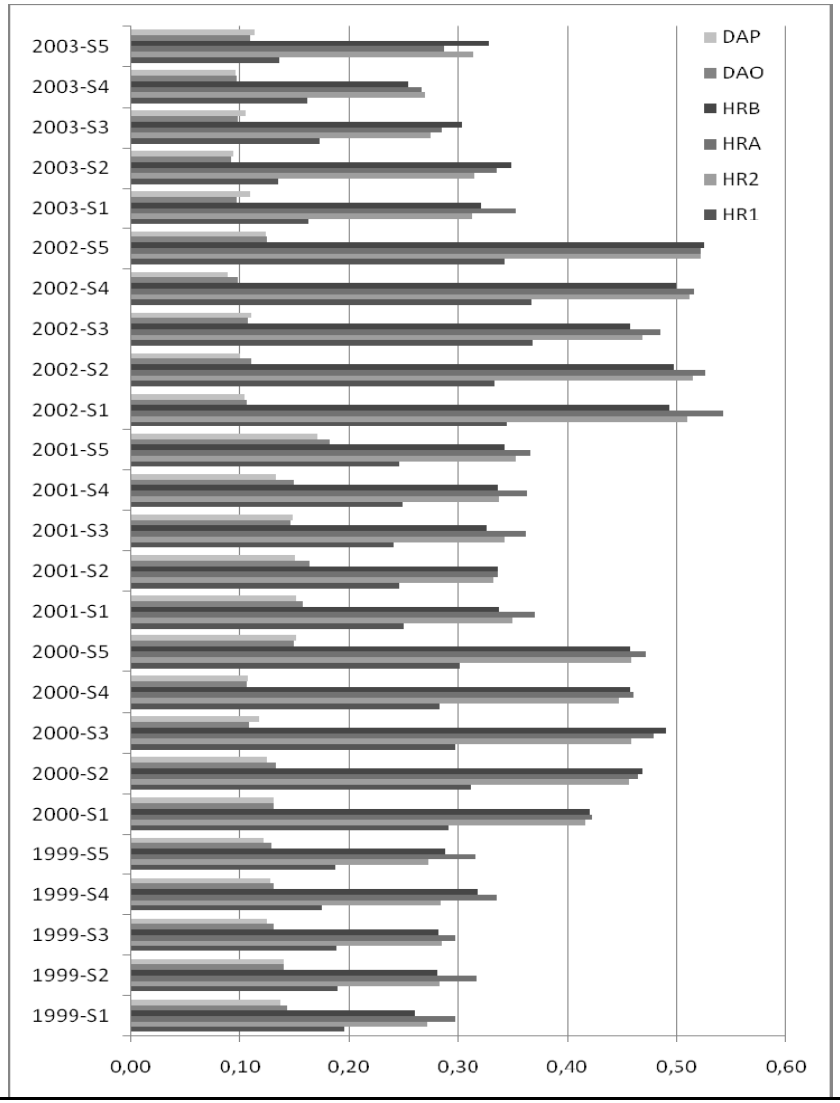
Simulation results

1. Frequency and Duration of Occurrence

2. Lost Energy (capacity factor)

3. Ramp Rates and Reserves Requirements

Lost Energy – Capacity factor



$$C_F = \frac{E_a}{N_h \cdot Cap}$$

Name	HR1	HR2	HRA	HRB	DAO	DAP
Capacity factor difference %	0,25	0,37	0,39	0,38	0,13	0,12
Equivalent full load hours	21,65	32,80	34,26	33,04	11,02	10,81

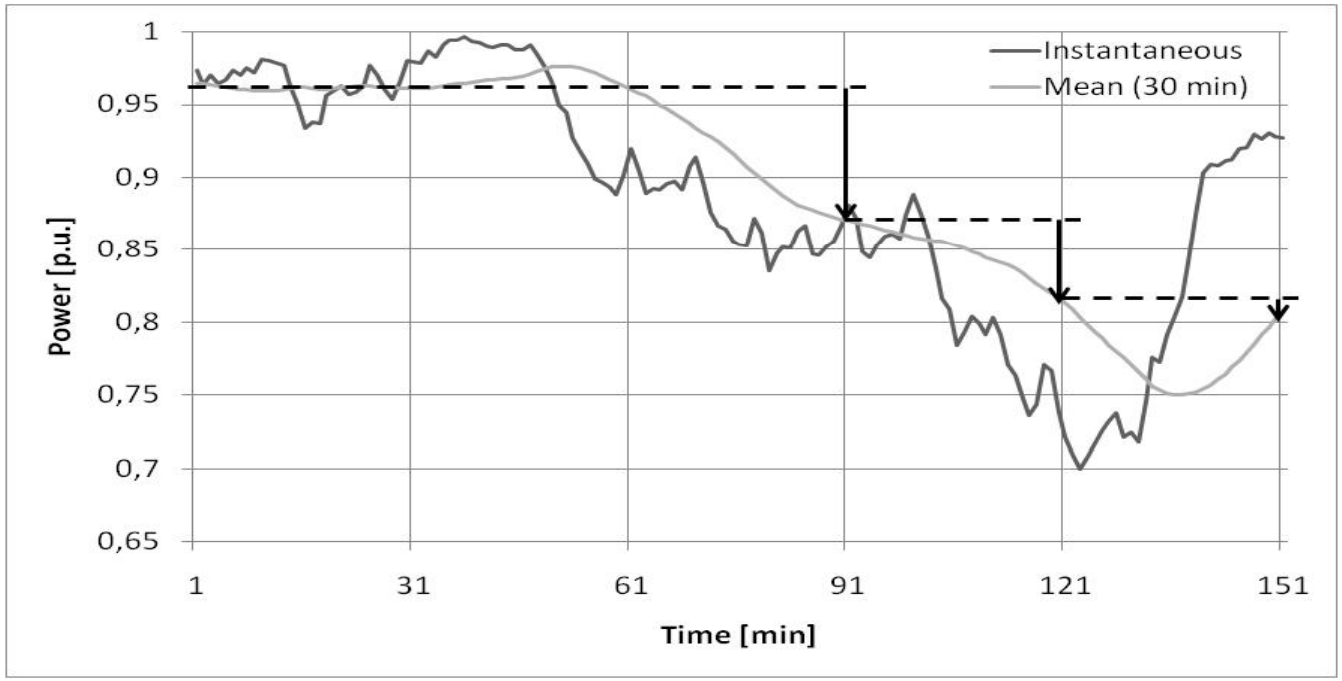
Simulation results

1. Frequency and Duration of Occurrence

2. Lost Energy (capacity factor)

3. Ramp Rates and Reserves Requirements

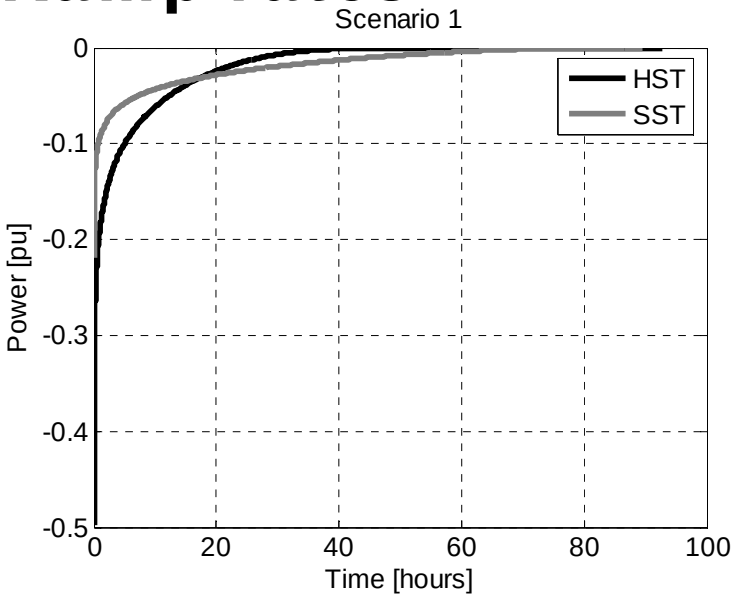
Ramp rates

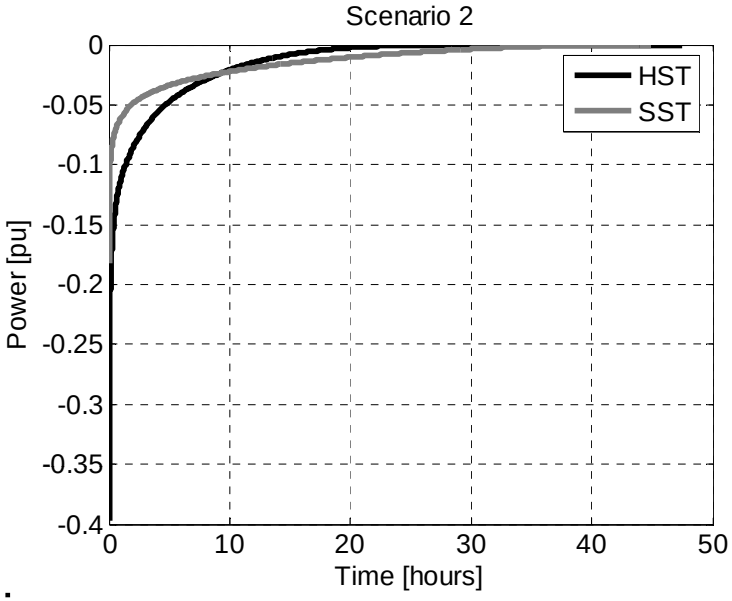


$$P_{\text{ramp}}(n) = P_{\text{mean}}(n+1) - P_{\text{mean}}(n)$$

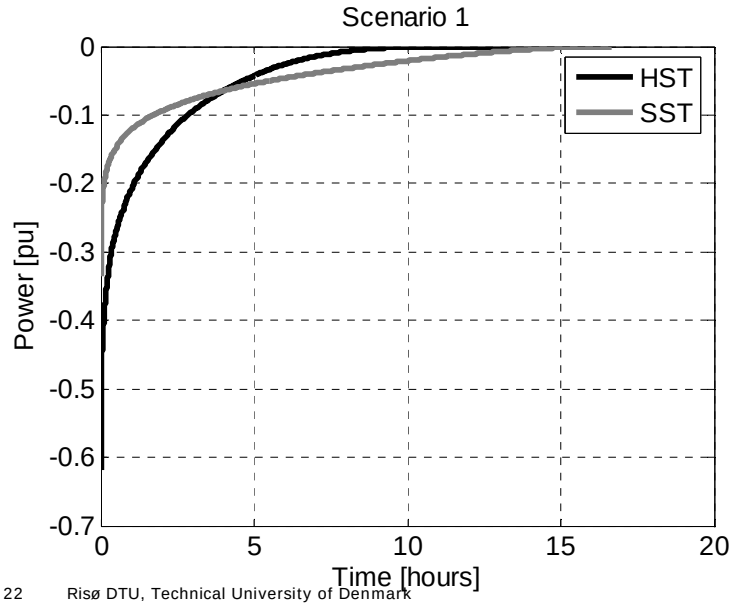
Ramp rates

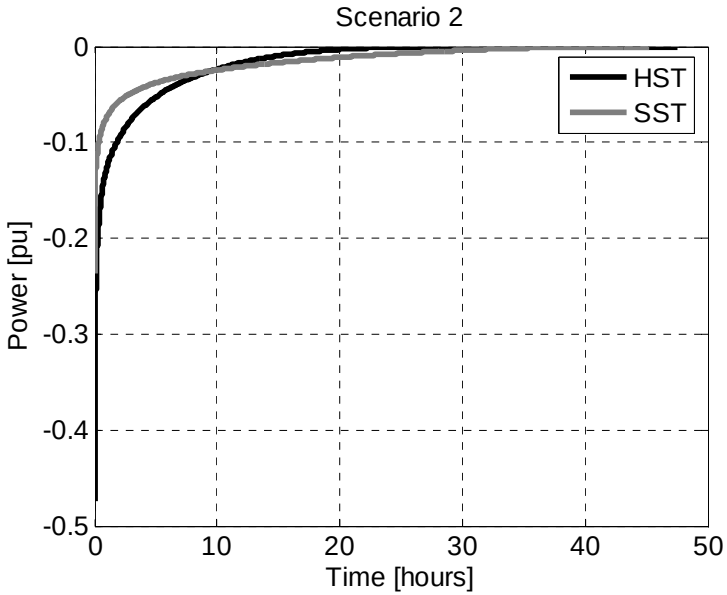
15 min



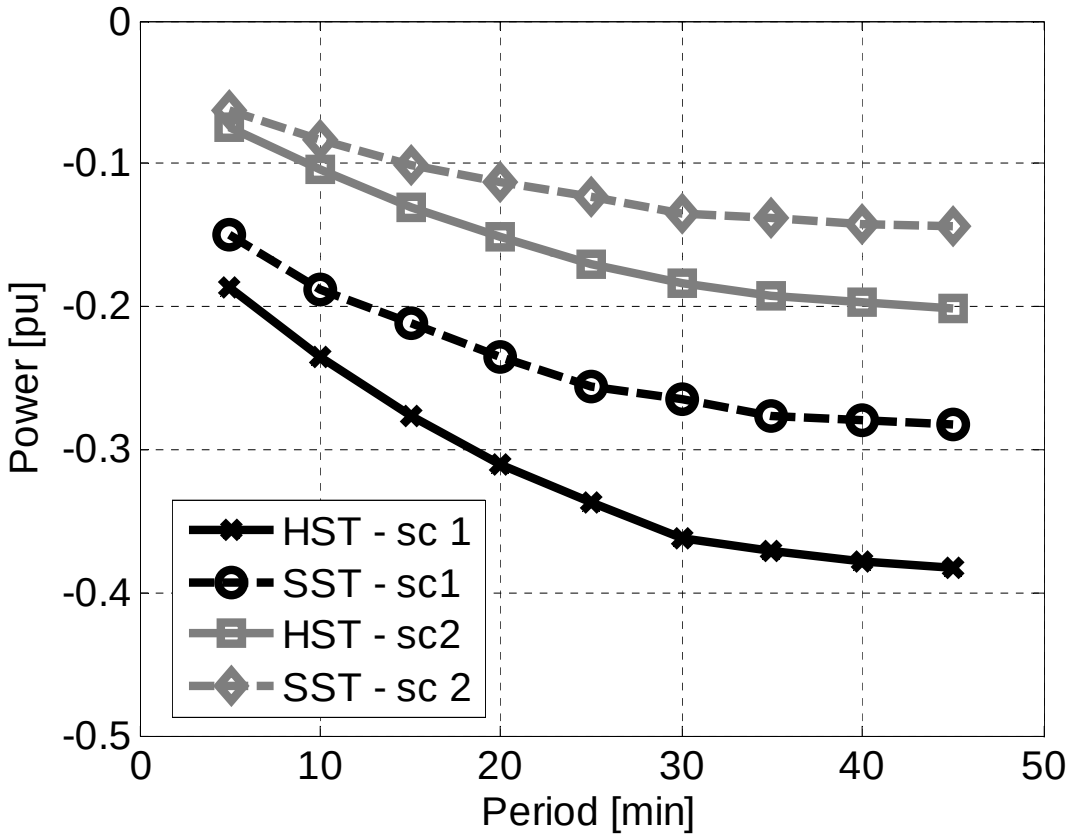


30 min





Ramp rates


0
-0.1
-0.2
-0.3
-0.4
-0.5
Power [pu]
0
10
20
30
40
50
Period [min]
HST - sc 1
SST - sc1
HST - sc2
SST - sc 2

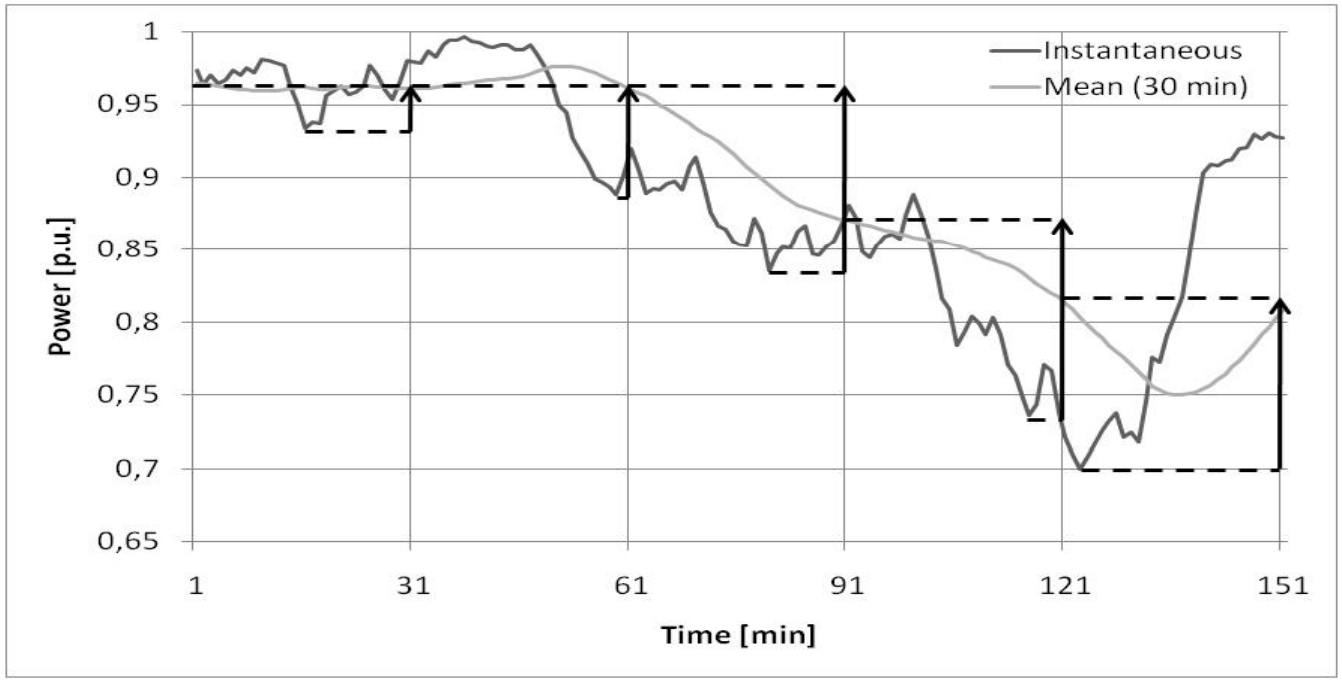
Simulation results

1. Frequency and Duration of Occurrence

2. Lost Energy (capacity factor)

3. Ramp Rates and Reserves Requirements

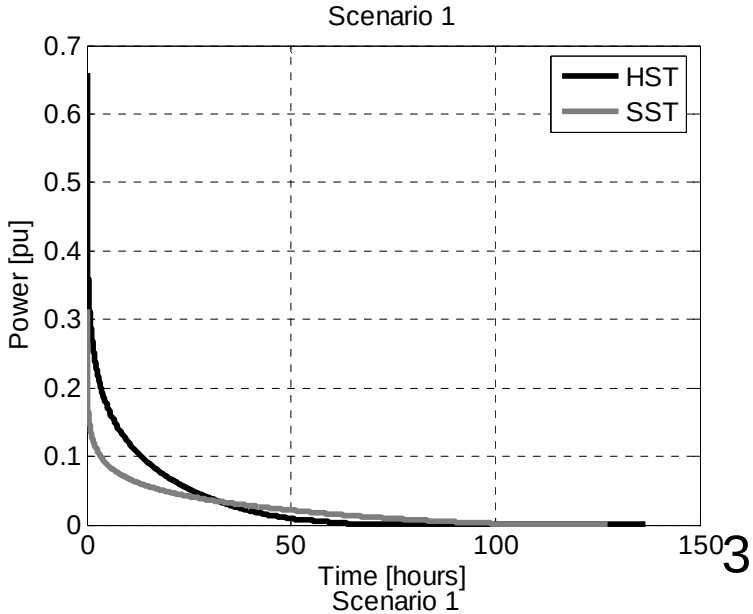
Reserve requirements

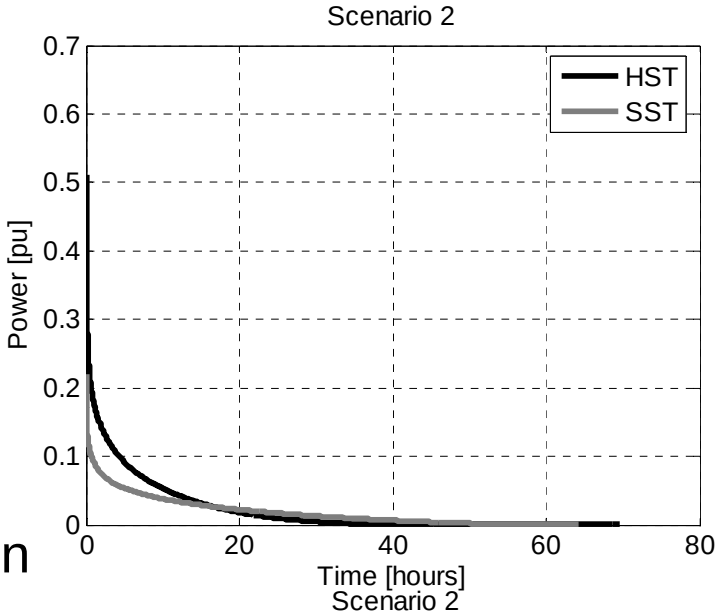


$$P_{\text{reserve}}(n) = P_{\text{mean}}(n) - P_{\text{min}}(n+1)$$

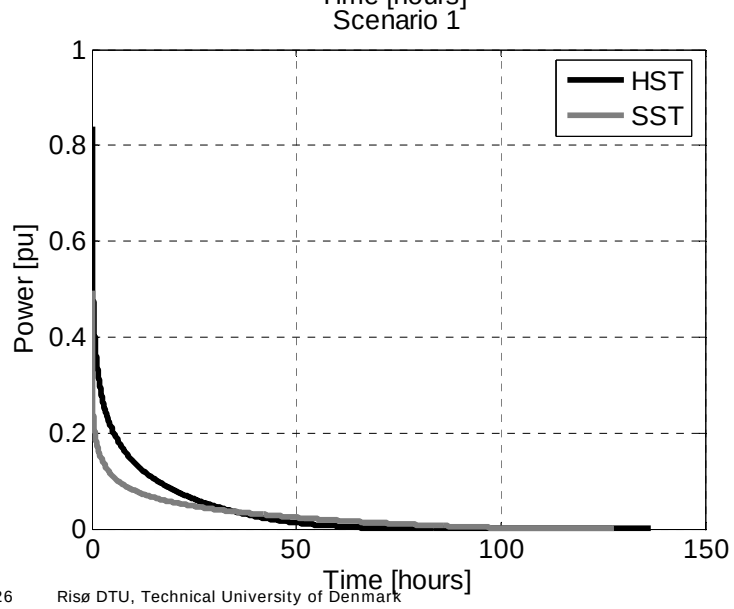
Reserve requirements

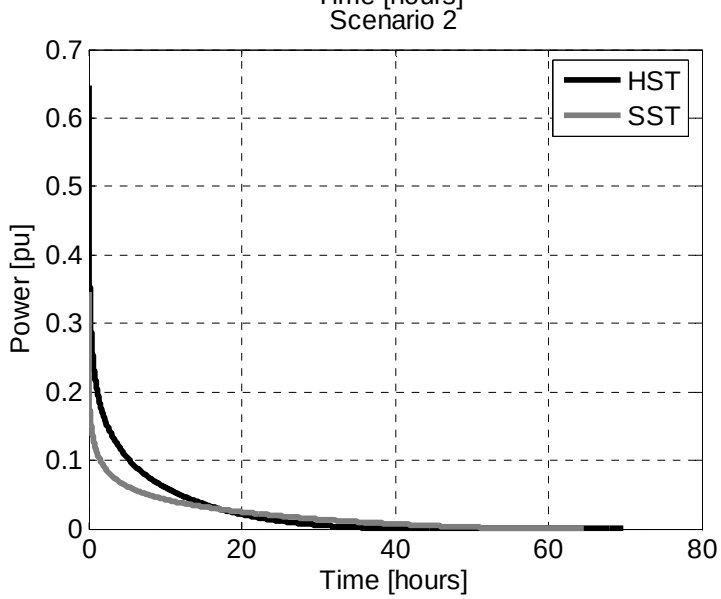
15 min



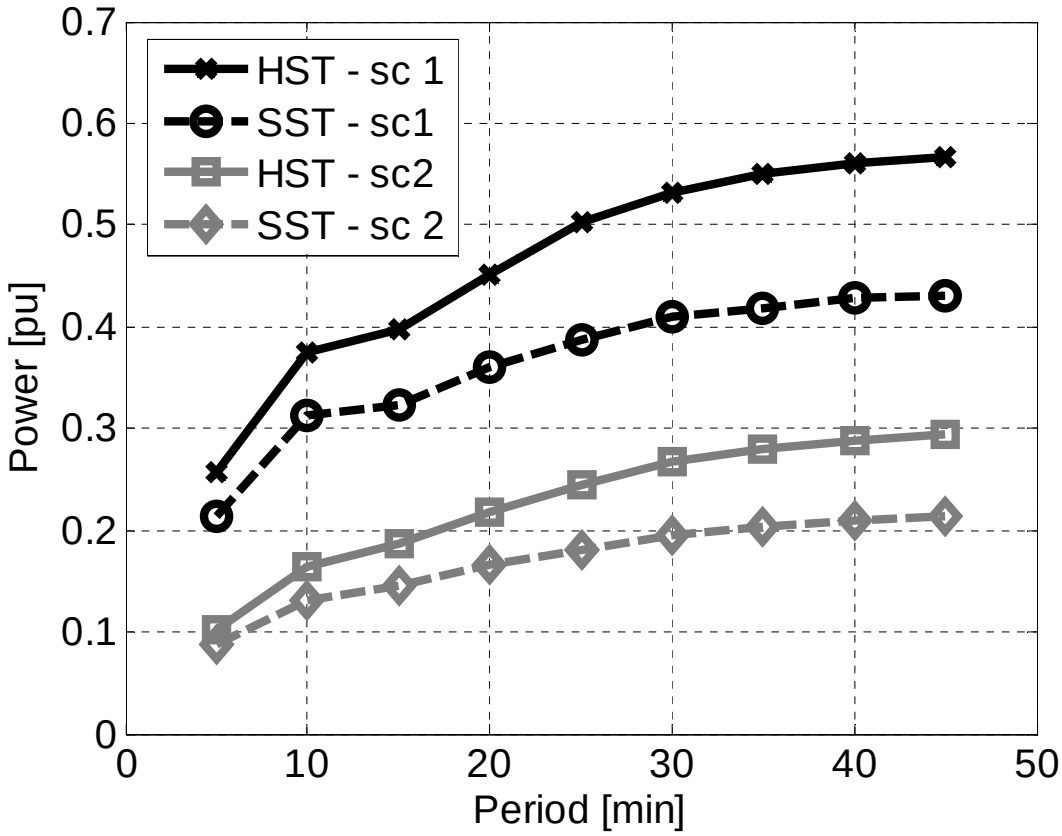


30 min





Reserves requirements



Conclusions

- Offshore wind farms operational under extreme wind conditions reliability analysis is important
- Control strategies play a crucial role in increasing the reliability of offshore wind farms power production under extreme wind conditions
- Availability of wind power production at power region level can be improved by proper wind farm location selection